CALIFORNIA DEPARTMENT OF TRANSPORTATION
OFFICE OF STRUCTURES DESIGN

Pile Shaft Analysis
Instructions for Users

INTRODUCTION

The analysis of laterally-loaded pile shaft requires consideration of the soil-structure interaction because both the soil and the structure combine to dictate the overall behavior. A designer's primary concern is to ensure that the anticipated loads will not result in excessive deflection of the structure or in excessive stress in the pile. Features of the program include:

1. The option to use p-y curves* specified by the user or to have the p-y curves generated internally. Internal p-y curves are based on the soil characteristics and assumptions for various types of soil.

2. The ability to analyze layered soils.

3. The option to use several types of pile head boundary conditions, including lateral and rotational springs.

4. The ability to specify pile properties as a function of depth.

*See General Notes on page 5

The program assumes that the pile remains elastic, and the user must be aware of the limitations of the analytical method. The limitations are as follows:

- The ability to analyze group pile effects is not included.
- Time effects, associated with sustained or cyclic loading, are not included but can be taken into account indirectly by adjusting the p-y curves. The effect of specifying cycles tends to soften the p-y curves (an automatic adjustment by program) to account for lubrication and water pumping effects at the pile-soil interfaces due to wave action. Note that this is a static analysis program. If an equivalent static load can be determined by some other method, the program may then be used for dynamic load conditions.
- Information regarding the response of complex soil profiles, for as layered soils, is extremely limited at present.
- Using panel input, the maximum pile length is 150 ft and minimum is 3 ft. However, these lengths may be changed in the XEDIT mode.
- A total of 30 p-y curves are allowed.
- The pile can be divided into a maximum of 10 segments (minimum segment = 3 ft). Each segment is assumed to have uniform cross sectional properties.

- Fractional segments (such as 6.2') are not allowed for panel screen input.
- Input up to 9 layers of soil data per run.
- Input up to 18 loading combinations for each run.
- Lateral loads (shear or moment) must be specified, or the program will not run. The program will not run if only an axial load or a distributed lateral load is applied.
- If the pile is not circular, the width of the pile perpendicular to the direction of loading is usually taken as the diameter.
- The program assumes all p-y curves either to be generated internally or input by the user.
- P-Y curves for soft rock have not been provided in the program. For more involved analysis, the user can input p-y curves to simulate rock-like conditions.
- The program is theoretically correct for large diameter (6' to 8') piles. But to date, program results have not been compared to field tests of piles larger than 3' in diameter.

The criteria* for generating the p-y curves incorporated in the program have been used in many design situations, and are thought to yield conservative estimates of soil response. The user should remember that the criteria are based on very limited data.

*See Reference 1 on page 7

GENERAL NOTES

- The following notes are summarized from documentation of the computer program COM624, written by Prof. Reese, University of Texas, Austin.
- The most important soil parameter needed to predict pile behavior in clay is the undrained shear strength, c.
- Variations in strain at 50% stress level, E50, have less of an effect on pile behavior than do variations in c.
- Variations in soil density, r(gamma), and modulus of subgrade reaction, k, have very little effect on pile behavior in clay.
- The most important parameter needed to predict pile behavior in sand is the internal friction angle, phi.
- Variations in r are more important for piles in sand than for piles in clay.
- Variations in k have very little effect on piles in sand.
- A p-y curve is defined as the soil resistance to pile deflection at various depths below the ground line. In general, these curves are non-linear and depend on several parameters including depth, shear strength, pile diameter, and load cycles.

- For sand layers (soil types 5 to 10), c is not used and may be left blank. For clay layers (soil types 1 to 4), the phi angle is not used and may be left blank. For soil type 0 (user input p-y curves), c, phi, and r are left blank.
- In order to consider a pile as a flexible member, a sufficient depth of embedment is required. Normally, a depth equal to the second inflection point of the deflection curve is probably acceptable.
- The soil parameters such as c, phi angle, r, k, and p-y curves are obtained from the Engineering Geology Branch, Translab.
- Tables 1 and 2 are built into the program in order to minimize tedious input for clay and sand parameters. They were suggested by Reese*. However, if the user desires to use different parameters than those shown in the tables, or finer increments, or to output p-y curves at a certain depths, the XEDIT mode may be used.

*See Reference 1 on page 7

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TABLE 1. Default values of E50 and k for clay

c (KSF)	E50 (%)	k(KCF)
c < .5	2	51.84
.5<= c <1	1	172.80
1<= c <2	0.7	518.40
2<= c <4	0.5	1728.00
c >= 4	0.4	5184.00

Remark: c - undrained shear strength
E50 - strain @ 50% stress level
k - modulus of subgrade reaction

TABLE 2. Default values of k for sand

Relative density	Loose	Medium	Dense
Submerged	34.6	103.7	216.0
Above water table	43.2	155.5	388.8

Remark: k - modulus of subgrade reaction (KCF)

REFERENCE

1. Reese, L. C., and Sullivan, W. R., "Documentation of Computer Program COM624", Geotechnical Engineering Center, The University of Texas, Austin, Texas, August, 1980.

DATA PREPARATION

The following input forms may be used to define a problem.
(Units will be in feet, kips and radians unless otherwise noted).

A. PILE GEOMETRY

1.	JOBID	-Any alphanumeric description of the job can be used up to 72 characters.
2.	E	-Modulus of elasticity of pile (default=468000).
3.	X	-Depth below top of pile to the ground line.
4.	Dn	-Pile diameter of segment n (n=1,2,....,10).
5.	An	-Pile area of segment n.
6.	In	-Moment of inertia of pile of segment n.
7.	Ln	-Length of segment n.
8.	PILE HEAD TYPE	-Defined on input screen (must be 1 to 4). See figures on page 11.
9.	CYCLIC LOAD	-Input a "0" for static load.
10.	PLOT	-Input a "y" for plots, otherwise no plots.

B. DISTRIBUTED LATERAL LOAD / ADDITIONAL PILE DIMENSIONS

(Distributed lateral load will be applied at the pile above ground line.)

C. SOIL DATA

(Self-explanatory on input screen)

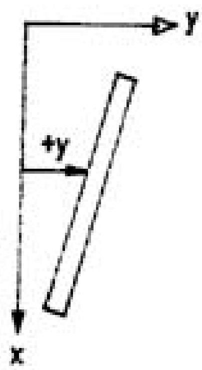
D. USER'S P-Y CURVE

(Under development)

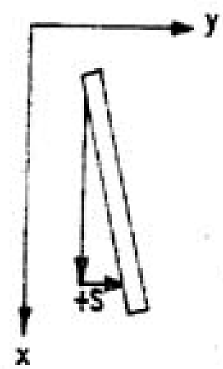
E. LOAD DATA at the pile head

(Provided on the input screen and based on the pile head type. Each set of loads provides a separate output.)

SIGN CONVENTION

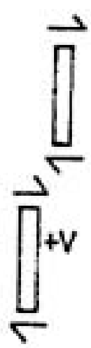


Deflection



Slope

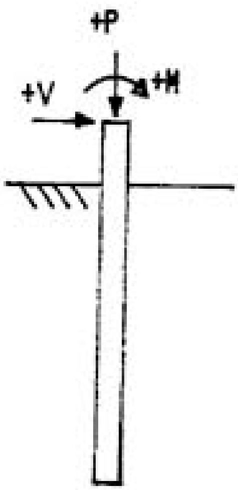
Moment
M



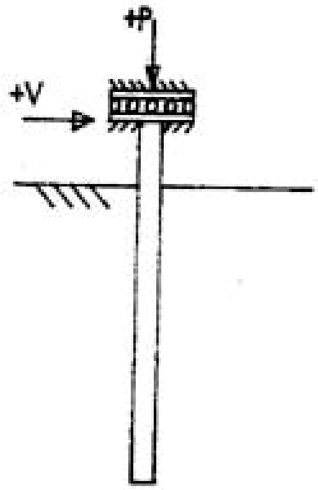
Shear
V

Soil Reaction
P

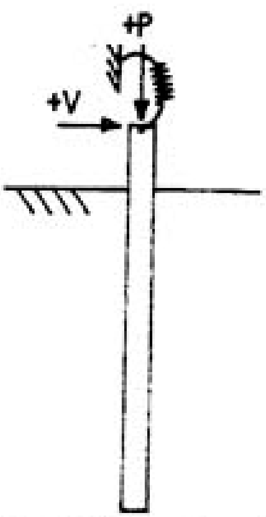
PILE HEAD BOUNDARY CONDITIONS



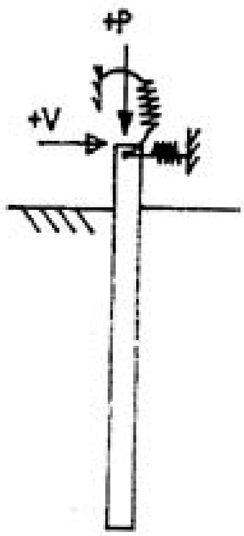
Type 1 Pile Head
Free to Rotate



Type 2 Pile Head
Fixed against Rotation



Type 3 Pile Head
Restrained with a
Rotational Spring



Type 4 Pile Head
Restrained with Lateral
and Rotational Springs

PANEL SCREENS

```
**************************************************************************************************
*                                                                                                *
*                                                                                                *
*    PILE GEOMETRY                                                                               *
*    JOBID: __________________________________________________________________________          *
*      E= _______ KSF                    P  |                                                    *
*                                          --+-+                                                 *
*                               H           | V   M(positive sign)                               *
*                               -------> V                                                       *
*    - - - - - - - - - - - - - - - -+=====+                                                      *
*      | X= _____ FT                |<--->| D1= ________   FT                                    *
*      |                            |     | A1= _________  FT**2                                 *
*      |                            |     | I1= __________ FT**4                                 *
*      V     GROUND LINE            |     | L1= ______     FT                                    *
*    -------------------------------|     |---------------------                                 *
*                                   |=====|                                                      *
*                                   |<--->| D2= ________   FT                                    *
*                                   |     | A2= _________  FT**2                                 *
*                                   |     | I2= __________ FT**4                                 *
*                                   |     | L2= ______     FT                                    *
*                                   |     |                                                      *
*      PILE HEAD TYPE : _                        CYCLIC LOAD : _______ CYCLES                    *
*           1 - FREE HEAD                               0 FOR STATIC LOAD                        *
*           2 - HEAD FIXED AGAINST ROTATION             PLOT : N                                 *
*           3 - HEAD RESTRAINED W/ A ROTATIONAL SPRING                                           *
*           4 - HEAD WITH LATERAL & ROTATIONAL SPRINGS                                           *
*                                                                                                *
*                                                                                                *
*                                                                                                *
**************************************************************************************************
```

```
*******************************************************************************************
*                                                                                         *
*                                                                                         *
*   DISTRIBUTED LATERAL LOAD FROM TOP OF PILE TO GROUND LINE:                             *
*               DISTANCE    FORCE          DISTANCE    FORCE                              *
*               FROM TOP                   FROM TOP                                       *
*                  FT       KIPS/FT           FT       KIPS/FT                            *
*           1  ________  ________      2  ________  ________                             *
*           3  ________  ________      4  ________  ________                             *
*           5  ________  ________      6  ________  ________                             *
*           7  ________  ________      8  ________  ________                             *
*           9  ________  ________     10  ________  ________                             *
*                                                                                         *
*   ADDITIONAL PILE DIMENSIONS:                                                           *
*        SEGMENT      DIAMETER     AREA        MOMENT OF     LENGTH                       *
*          NO.                                  INERTIA                                   *
*                        FT        FT**2         FT**4         FT                         *
*           3         ________  _________   __________    ______                          *
*           4         ________  _________   __________    ______                          *
*           5         ________  _________   __________    ______                          *
*           6         ________  _________   __________    ______                          *
*           7         ________  _________   __________    ______                          *
*           8         ________  _________   __________    ______                          *
*           9         ________  _________   __________    ______                          *
*          10         ________  _________   __________    ______                          *
*                                                                                         *
*   <ENTER>=CONT PF3=QUIT PF4=GEOM PF5=GEO2 PF6=SOIL PF7=P-Y PF8=LOAD PF9=FILE            *
*                                                                                         *
*                                                                                         *
*******************************************************************************************
```